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THE ZIMMERMAN PINE MOTH.[1]

By JOSEF BRUNNER, *Assistant in Forest Entomology, Forest Insect Investigations.*

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INTRODUCTION.

One of the insects of the order Lepidoptera very destructive to coniferous trees, and especially to yellow pine (*Pinus ponderosa*) in various sections of the West and, according to Zimmerman, Grote, and Kellicott, to white pine (*Pinus strobus*), Canadian or red pine (*P. resinosa*), Austrian pine (*P. austriaca*), Scotch pine (*P. sylvestris*), Swiss pine (*P. cembra*), and other pines in the East, is the Zimmerman pine moth (*Pinipestis zimmermani* Grote[2]). Aside from being largely the cause of "spike-top" (Pl. I) in mature timber, it spike-tops, stunts, and kills outright innumerable trees of the so-called "second growth." The timber of at least one area, thus far discovered, has been brought into such ill repute that carpenters and builders refuse to use it for anything in which "never-ending shrinkage" is objectionable.

Having noted during several seasons the severe injuries inflicted by the larvæ of this insect, the writer, at the suggestion of Dr. A. D. Hopkins, undertook, during the autumn of 1912, a systematic study of its seasonal history and habits, the recorded information on this insect being inadequate. This study was conducted during 1913–14 in conjunction with other work on insects which affect reproduction and

[1] *Pinipestis zimmermani* Grote. [2] Identification by August Busck.

NOTE.—This bulletin is of special interest to manufacturers and users of pine lumber from the Western States.

the development of forest trees, with a view of discovering possible methods of elimination or at least amelioration of its ravages.

Definite details were gathered only in certain areas within the States of Montana and Idaho, but correspondence with the other forest insect field stations in the West, together with larvæ collected and forwarded from those stations, proves that this moth occurs almost everywhere in the West. Considering that Packard records its occurrences in New York and Pennsylvania, it is evident that this insect is probably distributed over most of the United States. Its habits and the result of its larval work also apparently do not vary materially anywhere in its range. These facts lead to the conclusion that the remedy outlined below should be as effective in other regions as in the West.

DESCRIPTION OF THE INSECT.

THE ADULT.

The length of the moth (Pl. II, fig. 1) is about one-half inch. There is no appreciable difference in size and coloration between the two sexes although the general color of individual specimens varies from a light gray to a reddish gray and the body of specimens having the latter hue on head and thorax is usually dark gray. The underside of the entire insect is of a uniform gray color.

The wing expanse is from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. The fore wings are shaded reddish on the basal and terminal fields, the median space, divided from the latter by W-shaped lines, being blackish and gray, these two colors being again divided by a small white bar on a brownish field.

The hind wings are pale yellowish white, the color becoming deeper toward the terminal fringe, which is paler than that of the fore wings, on which it frequently shades to a dark gray. These characters agree fairly well with Grote's description.

THE LARVA.

When full grown the caterpillar (Pl. II, fig. 2) is about three-fourths of an inch in length. The head is chestnut brown, the mandibles black. The body is naked, with a series of dots, darker than the skin, from each of which issues a single bristle. It has three pairs of thoracic legs, four pairs of abdominal prolegs, and a pair of anal claspers. The body varies greatly in color, which ranges from a dirty white, through reddish yellow, to a vivid green. The larva found in yellow pine is almost invariably gray-brown, resembling the color of the bark of the host tree, while those in Douglas fir are of such a vivid green color that it seems almost incredible that they should be representatives of the same species which infests pine. Rearing them to the adult stage, however, always dispels any doubt in this regard.

Variations in color, about which Grote and Kellicott differ, are evidently merely a matter of host differences.

THE PUPA.

Freshly formed chrysalids are of a light brown color, which changes to blackish brown as the moth within develops toward maturity.

The chrysalis is cylindrical, about three-fourths of an inch long, rather slender, and without spines on the segments. This last character makes it readily distinguishable from a sesiid pupa, which is frequently found under somewhat similar conditions.

SEASONAL HISTORY AND HABITS.

While adults emerge and mate from about May 1 to September 15, the maximum flight of the moths occurs during the month of July. They appear to be rather long lived, many 2-weeks-old specimens reared in the laboratory being as ready to take wing when disturbed as when they had just burst the bonds of the chrysalis. No other species of moths reared in captivity the larvæ of which feed on internal tree tissues were observed to live more than 10 days after emergence under similar conditions. The longevity of the Zimmerman moths evidently extends the period of mating beyond the general flight, and consequently fertilized eggs are deposited during any of the milder months.

Larvæ of all sizes, except the most minute in winter, may be found at any time of the year.

Though frequently but a single larva is found in a wound, the writer is of the firm opinion that eggs are almost invariably deposited in clusters. In the many observations while the larva was less than three-eighths of an inch in length six or more of them were always found in one infested spot. From a specimen of yellow pine 6 inches in length and but 1 inch in diameter showing old work, which was placed in a breeding cage during the middle of December, a month and a half after heavy frost had ended all outdoor insect activity, seven larvæ emerged early in January from eggs which had evidently been deposited on this small specimen during the previous late autumn. (Pl. II, fig. 3.)

Again, it is often the case that a space a foot or more wide and several feet long on a tree trunk has the cambium literally honeycombed with the tunnels of numerous larvæ. In one such case the writer found 27 nearly mature Pinipestis larvæ at work.

In mature stands, in "spike-tops" in the making, and at the bases of new spikes, plural infestation is evidently the rule.

This conclusion is verified to some extent by the observations of Mr. W. D. Edmonston at the Forest Insect Field Stations at Ashland, Oreg., and later at Colorado Springs, Colo., and by quite a number of larvæ and valuable notes that he sent to the writer. These notes generally end with the statement: "Under bark in hardened pitch

were found empty pupa cases," or "Empty chrysalids were found in the pitch masses."

Since no other pitch moth so seriously destructive to the trunks of mature or nearly mature trees leaves the entire pupa shell *within* the bark or the pitch which sheltered the immature insect, its identity is quite easily determined.

The eggs deposited in July appear to hatch within about two weeks. During the latter part of August the young larva manifests its presence in infested trees rather plainly by the mixture of coarse castings and brown bark dust which is thrown out through the entrance and other holes in the bark made by the larva. Unlike the larvæ of the sesiid pitch moths, the pine moth caterpillar does not work into the cambium and stay there. Quite often, if not always, after attaining nearly half its full growth, it leaves the place where it hatched and drills into the tree tissues again at a spot which presumably suits it better, not infrequently several feet away from the original spot. To this migratory habit probably must be attributed the frequent occurrence of but one larva in a wound, except in instances where the work of woodpeckers accounts for their isolation. This assumption seems to be supported by the fact that all such hermits when located are developed well toward maturity.

As the larva grows and the inactive season approaches, this promiscuous gnawing of holes in the bark ceases. In no case even where most of them remain where they first saw the light is migration resumed the following spring. In the spring each larva prepares for pupation in its own individual tunnel, though under the same space of infestation, by lining it with silky thread. Packard states [1] that "the worm in July spins a whitish, thin, papery cocoon in the mass of exuding pitch, which seems to act as a protection to both the larva and the chrysalis." This applies to the insect in the East. In the West the caterpillar of the pine pest restricts its weaving operations before pupating to the above-mentioned lining of the tunnel. Cocoons which answer Packard's description are frequently found in these tunnels, but they are of a parasite which will be referred to later.

On approaching maturity, about the middle of June, the larva grows sluggish and is found to be transformed into the chrysalis within a few hours. When the moth has attained full development, 29 days from the time the pupa was formed and a year after the egg was laid, it merely bursts the chrysalid skin, leaving the empty shell within the tunnel, and pushes its way out through the very thin pitch covering at the mouth of the tunnel. The period of pupation in captivity under very varying temperatures and during all seasons

[1] Packard, A. S., Insects Injurious to Forest and Shade Trees. 5th Rpt. U. S. Ent. Com., 955 p. (p. 731), 38 pl., 306 fig., 1886–1890.

within a period of two years has in all cases proved to be exactly 29 days.

Eggs laid the previous autumn hatch in early spring and develop into adults during August and September of the same year, while eggs deposited during May evidently develop into adults early the following spring.

RELATION TO OTHER INSECTS.

In the northern Rocky Mountain region *Pissodes schwarzi* Hopk.[1] is a common associate of the pine moth in yellow pine, if the trees are attacked near the base. It appears that there the moth takes as frequent advantage of the work of the beetle as the beetle does of the moth's. The result of infestation by either of them is exactly alike, although the latter's attack is by no means restricted to the base of trees, while the work of the beetle is rarely found more than 2 or 3 feet above ground.

Sesia brunneri Busck,[2] wherever it exists (at present known in Montana and southern Idaho), is frequently associated with Pinipestis in yellow and lodgepole pine. While the attack by the Sesia in lodgepole pine appears to invite and to be the cause of subsequent infestation by the Pinipestis, the former frequently takes advantage of the work of the latter in yellow pine greatly to augment its own numbers. When this sesiid moth attacks a tree primarily it invariably deposits but one egg at a spot; but when it infests the pine moth's work in yellow pine it seems always to deposit quite a number of eggs. The writer has taken as many as six nearly mature Sesia larvæ from a single space surrounding a spot previously infested by the pine moth. The space infested by the latter is always killed and subsequent infestation can only occur at the border of such a spot. As the Sesia larva works parallel with the grain of the wood, its infestation of Pinipestis work becomes evident on the surface of the surrounding fresh bark by regular pitch masses of the size of a silver dollar instead of the general pitchiness which characterizes pine pest infestation, owing to the numerous holes it makes in the bark.

If the pine moth reinfests such a Sesia-infested space, its larvæ, feeding on the strictly fresh cambium surrounding it, usually stop the necessary flow of sap to the space occupied by the Sesia and the latter is starved to death on this account. To comprehend how this is possible, it must be understood that the sesiid larva is not able to move around at will on the surface of the bark, that it is apparently unwilling, if not unable, to cross spaces already sapped by other insects, and that it requires two years to complete its life cycle.

Two small moths of the genus Laspeyresia,[3] one in yellow pine and one in Douglas fir, frequently breed in the work of the pine moth in

[1] Identified by A. D. Hopkins.

[2] Busck, August. Descriptions of new microlepidoptera of forest trees. *In* Proc. Ent. Soc. Washington, v. 16, no. 4, p. 143–150, pl. 7–8, 1914.

[3] Identified by August Busck.

considerable numbers. However, the relation seems to be of no economic importance.

In Montana and Idaho another species of Pinipestis, *P. cambiicola* Dyar,[1] is one of the most important factors in regard to the existence of *Pinipestis zimmermani* Grote. It infests during the latter part of June the cambium of the terminal branches of mature yellow pine, and many of these wounds are subsequently reinfested by the latter year after year. The work of this insect is almost invariably the primary cause of the knobby growth on branches in which the Zimmerman pine moth breeds undisturbed by woodpeckers or parasites, and this moth must therefore be regarded as a provider of brood trees for the more destructive *Pinipestis zimmermani*. (Pl. III.)

RELATION TO NATURAL ENEMIES.

In most sections of the Rocky Mountains the Rocky Mountain hairy woodpecker (*Dryobates villosus monticola*) is unquestionably the most efficient natural force in restraining the Zimmerman pine moth. Thousands of trees are each year regularly infested by the moth in comparatively small areas, and this bird as regularly destroys almost all of the larvae in all of them during early winter, so that, although hundreds of trees may be examined at a time, it is only on rare occasions that larvæ are found after December in wounds in the trunks of trees which had been infested during the previous summer. This woodpecker seems to have a decided preference for the caterpillar of the pine moth wherever the writer and the entomological rangers assigned to the Northern Rocky Mountain Field Station have had opportunities for observation. In the extreme southeastern part of Montana, and particularly that portion covered by the Northern Cheyenne Indian Reservation and by the Custer National Forest, the moth has apparently neither bird nor insect enemies. In all other localities this woodpecker is fully able to eliminate this insect as a serious factor in timber destruction. Especially will the work of the bird become effective when the habits of the moth are more generally understood and its "brood trees" are eliminated through use by man.

From reports from other field stations the writer concludes that from Idaho west toward the Pacific coast and in the southern Rocky Mountain region woodpeckers are of no consequence as a check upon this insect. But, considering that much confusion still exists concerning the identity of Pinipestis among the "pitch moths," this conclusion may prove erroneous when more thorough information is available.

The woodpecker never molests the caterpillars of the pine moth which live under "spike tops" and in knobby branches on certain

[1] Identified by H. G. Dyar.

REPEATED INJURY BY THE ZIMMERMAN PINE MOTH TO LARGE TREE, RESULTING IN "SPIKE-TOP." (ORIGINAL.)

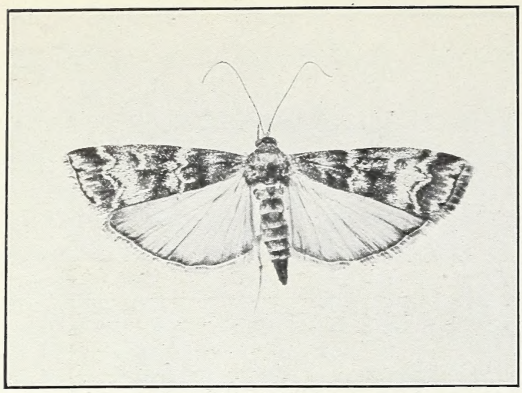


FIG. 1.—ADULT MOTH. SLIGHTLY ENLARGED. (ORIGINAL.)

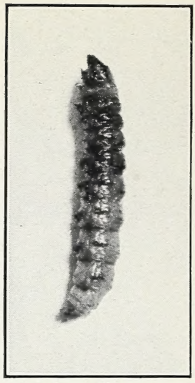


FIG. 2.—LARVA. TWICE ENLARGED. (ORIGINAL.)

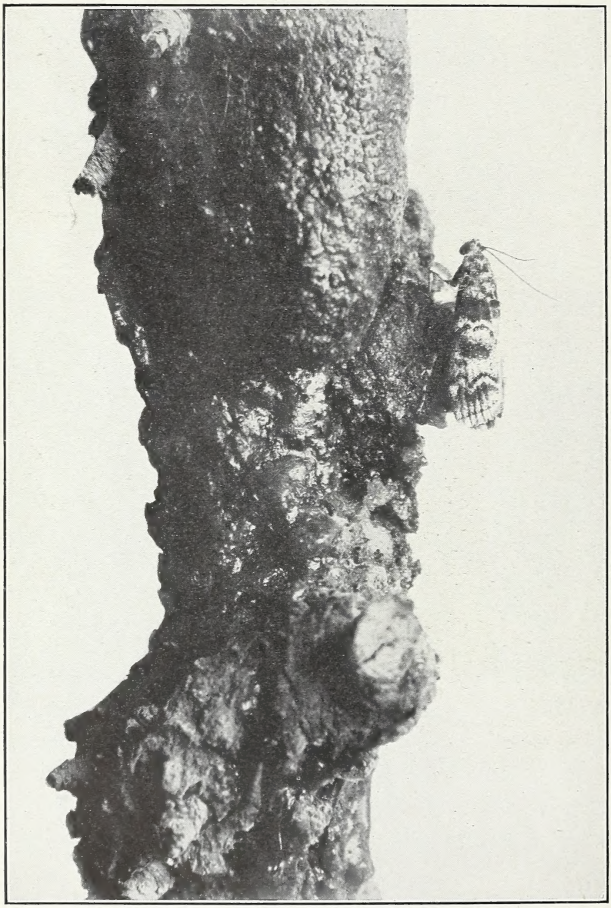
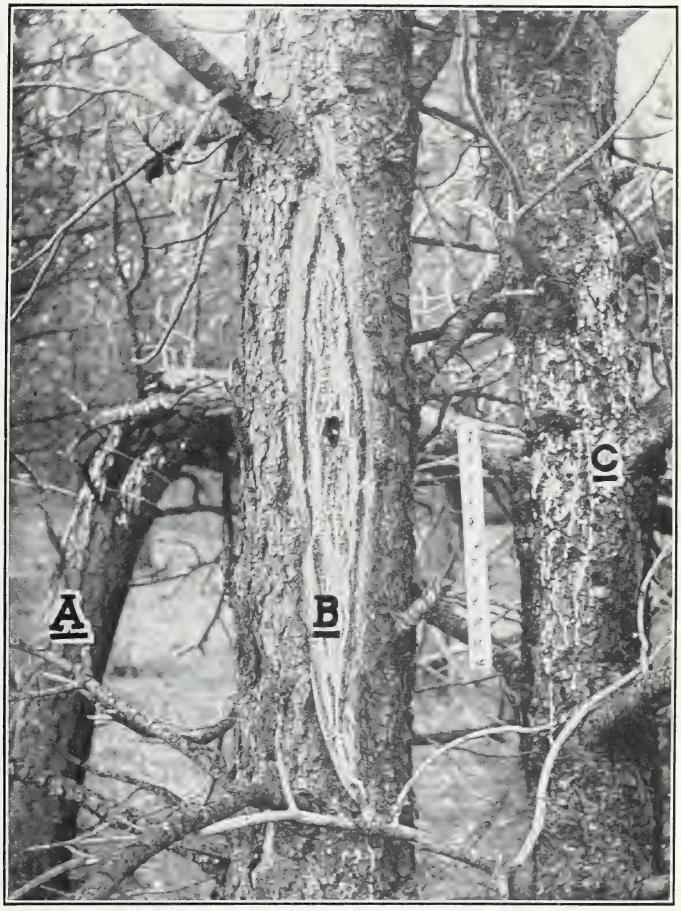


FIG. 3.—MOTH ON SECTION OF TREE TRUNK, SHOWING CHARACTER OF INJURY. SEVEN LARVÆ WERE FOUND IN THE BARK OF THIS SECTION IN DECEMBER. (ORIGINAL.)

THE ZIMMERMAN PINE MOTH (PINIPESTIS ZIMMERMANI) AND ITS WORK.

PINE SHOOT SHOWING PRIMARY INJURY BY PINIPESTIS CAMBIICOLA, AND INFESTATION, TWO YEARS LATER, BY THE ZIMMERMAN PINE MOTH. NATURAL SIZE. (ORIGINAL.)

PINE TREE SHOWING RESULT OF REPEATED ATTACK BY THE ZIMMERMAN PINE MOTH, AND THE INJURY AGGRAVATED BY THE ROCKY MOUNTAIN HAIRY WOODPECKER IN ITS SEARCH FOR THE LARVA. (ORIGINAL.)



YELLOW PINE SHOWING CHARACTER OF INJURY BY THE ZIMMERMAN PINE MOTH.

A, Tree broken at injury; *B*, tree attacked by insect and insect removed by woodpeckers; *C*, tree girdled and killed by the insect. (Original.)

CROSS SECTION OF PINE SAPLING SHOWING EFFECT OF INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

CROSS SECTION OF OLD, SLOWLY-GROWING YELLOW PINE SHOWING INFESTATION BY THE ZIMMERMAN PINE MOTH AND ITS INJURY IN BARK. (ORIGINAL.)

PINE TREE SHOWING EFFECT OF CONTINUOUS INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

LONGITUDINAL SECTION OF YELLOW PINE SAPLING SHOWING RESULTING DAMAGE TO WOOD FROM ATTACK BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

FIGS. 1, 2, 3.—TYPICAL YELLOW-PINE "BROOD TREES" OF THE ZIMMERMAN PINE MOTH.

The removal of such trees and the burning of the affected parts is the most effective measure for the control of this pest. (Original.)

OLD YELLOW-PINE TREE SHOWING RESULT OF INJURY TO TOP BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

mature trees (see *Pinipestis cambiicola*, p. 6) and this is evidently the reason why its activities bear no permanent fruit. Considering also that the birds in hunting for the larvæ strip the trees of as much bark and cambium as the moth larvæ destroy in one generation, and that this operation is repeated each season, it is doubtful whether the woodpecker cure is not as bad as or even worse than the moth evil, when one considers that the brood trees are allowed to replenish the ranks of the insect year after year. (Pl. IV.)

The cocoon of a pimplinid of a new genus and new species [1] is frequently found in the tunnels of the pine moth in Montana and Idaho. In some localities this parasite kills as many as 80 per cent of the larvæ of the moth in second-growth trees. As the parasite cocoons are not molested by woodpeckers, a full quota of this fly emerges during the first warm days of each spring. While this parasite greatly aids in checking the increase of the moth from larvæ which infest second growth, it fails, as does the woodpecker, to pursue the caterpillars in the above-mentioned brood trees. Hence it is as much of a signal failure as is the bird.

Another, somewhat larger parasite (*Ichneumon* n. sp.[1]) is frequently found during winter in the chrysalis of the moth. The moth does not pass the winter in the pupal stage, and chrysalids found at that time always contain the parasitic fly, which, like the pimplinid, emerges during early spring. It is apparently less numerous than the latter and consequently of still less economic importance.

There seems to be justification for the conclusion that, without man taking a hand by eliminating the main propagating opportunities, no natural enemy of the moth will ever render it harmless. With human aid these agents will accomplish all that can be reasonably expected of them, i. e., the elimination of the ravages in rationally managed woodlands.

HABITAT AND HOST TREES.

Open, sunny stands of timber are those most affected by the Zimmerman pine moth. Slashings, on which reproduction has reached a height of 10 feet or more, having a scattered stand of mature trees, which were left standing to reseed the area or on account of being unfit for logs, invariably contain the greatest amount of pine-moth injury. It appears to be an absolute necessity to the insects' existence in a locality stocked with second growth, that the stand contain some of these specimens, which constitute brood trees for this insect. Where the mature timber has been cut clean over quite large areas, so that the chance for influx from without is remote, the insect does no damage, even though the ground may be stocked with an ideal

[1] Determined by S. A. Rohwer.

stand of second growth. Yellow pine, lodgepole pine, and Douglas fir are the tree species thus far noted to be subject to infestation by this insect in the West. Out of a hundred trees so infested about 80 per cent are yellow pine, 15 per cent lodgepole pine, and 5 per cent Douglas fir. Trees with a thick layer of fresh bark and cambium, as well as the more vigorous growers, are preferred for attack. All sizes, from but a few inches to several feet in diameter, are subject to infestation; but it is the mature trees which furnish the most favorable means of existence for this moth, while in the smaller ones, up to about a foot in diameter, it does the greater damage. (Pl. V.)

CHARACTER OF INJURY AND WORK OF LARVÆ.

The moth, as a rule, attacks mature trees from between 10 to 30 feet from the top down, and second growth from about breast high up to from 35 to 40 feet. Infestation nearer the top or base occurs only to a very limited extent.

As stated under "Seasonal history" (p. 4), fresh infestation is only indicated by the castings on the surface area of the attacked trees. If this area is very heavily infested, as in the case cited above, where the writer found 27 nearly mature larvæ in a space less than 5 feet in length by about 1 foot in width, there is at no time any other indication observable. The bark dries up without exuding pitch, as if scorched by extreme heat, and several years after the insect has vacated the bark drops off and the injury becomes manifest to the average passer-by. Usually, however, in such cases some larvæ leave the point originally infested and bury themselves higher up near a branch of the same tree. The pitch tube at the entrance of this tunnel invites close examination of the entire tree, whereupon the less conspicuous, yet heavy infestation is almost sure to be detected. (Pls. VI and VII.)

During the spring following infestation drops of pitch usually begin to ooze out of the tunnels in the bark and cover the surface of the average wound with a uniform, thin layer, somewhat similar in appearance to a liberal application of paint with a brush. The inner bark assumes a spongy appearance and gains in thickness, which tightens and even breaks the outer bark, together with the dried pitch covering it. The entire infested space finally presents a strikingly rough aspect which resembles the injury of no insect except *Pissodes schwarzi*, which produces a similar effect at the base of trees.

By repeated infestation at the border of the wound, in the course of years the tree is gradually girdled and the part above the collar dies and finally rots off at its base, provided the moth abandons the tree at this stage. But frequently infestation continues downward, on young trees usually until the lower branches, which by that time

show a tendency to develop into tops, are reached and the trees killed, and on mature ones to a point where the thickness of the bark fails to suit the insect. (Pl. VIII.)

On wounds infested by a single larva a pitch tube, resembling that produced by sesiid pitch moths, is usually formed, presumably because one larva alone is not capable of cutting as near the surface as when several work together in one space. In the latter case the tunnels cross and recross continuously, and when a larva strikes the tunnel of another, which must happen frequently, it usually cuts to the surface in order to avoid the solidified pitch. To the presence of the larva so very near and even at the surface of the bark must be attributed its rather heavy parasitization in localities where its parasite exists, because larvæ living singly are very seldom parasitized.

EFFECT OF INFESTATION ON TREE GROWTH AND FOREST.

It is obvious that the killing of many trees in stands preferred by the moth results in too great a thinning out of the stand. This wastage of ground is further augmented by the permanent stunting of a still greater number of trees by the insect's work, because the space taken up by such scrubs would just as readily accommodate thrifty, well-formed trees.

Moreover, the wood from trees that have been infested by the moth is invariably so permeated with pitch that the lumber cut from such logs is either materially reduced in value or is rendered wholly unfit for commercial use. (Pl. IX.) From one part of southeastern Montana, where this moth is especially abundant and a large percentage of the trees are pitch soaked, the lumber is, for this reason, only used for sheds, etc., where shrinkage can be discounted; the users find it cheaper to have the better material shipped in than to pick it out of the local stuff and throw half of it away unless it is needed for the less particular purposes indicated. To the writer this practice at first seemed rather to indicate prejudice against the home product, because there is a large amount of first-grade lumber produced along with the bad. However, the pine moth is responsible for this condition, as was abundantly proved by examination of its injury in the district. The manner in which the moth's work "pitchifies" the wood is best seen in the well-known tops which have been infested by it. From these tops the bark has dropped off, but the surface of the wood has a roughened appearance and the tissues are literally saturated with pitch, while at the lower end, where the infestation ended and the wood was not pitchified in the process, the spike is rotted off from the tree. This insect's work alone accounts for the fact that the extreme top of a tree may be excessively pitchy, while the rest of the same tree is not.

REMEDY.

There is probably no other seriously injurious insect which can be eliminated with less expense and trouble than the Zimmerman pine moth, because practically everywhere, wherever its existence is causing real damage, the country is readily accessible, being either already logged over or adjacent to settled farming land.

In slashings the remedy consists in logging, thus removing the mature trees as soon as the area is reseeded, and in any other wood lot, where it shows its presence in the second growth, in merely using all "spike-topped," lightning-struck, and heavily branched mature trees for firewood or domestic purposes. These are the "brood trees" in the great majority of cases, and their disposal ends the trouble in the growing trees. The larva in these three types is found at the base of the spike, along the scar caused by the bolt, and in the knobby growths on the branches which are the result of primary injury by *Pinipestis cambiicola* (in the West) and probably other insects. The affected parts should be destroyed, the simplest way being to burn them before the arrival of spring. The judicious choosing of the right trees for firewood for home consumption alone would prevent on many farms further damage by this insect to the growing trees. In one wood lot east of Missoula, Mont., covering about 40 acres of a quarter-section farm, 25 per cent of the second growth had been infested annually for several seasons, and the cutting of only three overmature trees during 1913–14 for firewood ended the damage absolutely. One of them was a still infested spike-top and two were full of knobby branches, also infested. There are still about 80 overmature trees standing on that farm, but the three cut were evidently, as supposed before the cutting, the only "brood trees," and, as the woodpeckers had taken care of the infestation in second-growth trees, the elimination of the moth at that place was a natural result of the disposal of these trees. (Pls. X and XI.)

In a locality about 5 miles north of Missoula, Mont., where at least 3,000 second-growth trees are infested and reinfested annually, the writer is positive that the cutting of not more than 24 overmature "brood trees" in a stand of about 1,000 of the same age as these would effectively end the continuous depreciation. In other localities not so thoroughly examined, the proportion of work necessary to end the trouble appears to average about the same. Even in southeastern Montana, though the moth is not subject there either to woodpeckers or parasites, the insect damage could be greatly reduced, if not eliminated, by disposing of the "brood trees" by merely selecting them for fuel.

CONCLUSION.

It is evident that natural agencies have not succeeded in preventing, and will not be able in the future to prevent, serious damage by this moth unless man aids their efforts by disposing of such trees as have fulfilled their usefulness in the forest and wood lot, and which, instead of being an asset there, have become a menace. To end "spike topping" in mature stands, and to eliminate damage in growing timber, or at least reduce it to a negligible amount, it is necessary to remove (1) those trees which, below the spike, show branches with yellow needles (a certain indication of present infestation), (2) those which are struck by lightning and remain green, as the moth usually breeds in great numbers along the lightning scars, and (3) those which display knobby growths on branches, they being in many localities the most prolific source of replenishment of the moth.

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Pages 731–733. *Nephopteryx* (*Pinipestis*) *zimmermanni* Grote.

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